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A Practical Investigation of the Effect of Reciprocity Law Failure in the Wollensax Fastax High Speed Camera WF-3

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by

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INTRODUCTION

Density changes due to reciprocity failure in high speed photography are widely known. Extremely short exposures require very intense illumination resulting in loss of density and thus necessitating a camera exposure increase. Experimentation by manufacturers has produced reciprocity failure curves for various emulsions. This investigation is an attempt to graphically illustrate the density change produced on one emulsion in the Fastax high speed system. Although it is assumed that reciprocity law failure is the largest factor contributing to the change, the action of the whole system on the emulsion (and including the emulsion), must be taken into account. This has necessitated a statistical analysis and presentation of the data obtained.

PROCEDURE

Three frame speeds (800, 2500 and 6500 pps.) were chosen so to cover a large area of exposure. The speeds were selected arbitrarily thus to avoid any bias or possible effects due to multiples of exposure times or other such factors. Nine one hundred foot rolls of Cine-Kodak Tri-X Negative emulsion were exposed in a Fastax High Speed Camera WF-3 (16mm) using the Fastax Goose Control Unit Model J-515 as the voltage and booster regulator. Exposures were made on a target (Fig. 1) containing four reflection densities, 0.00 (densitometer zero), 0.35, 0.65 and 1.82.

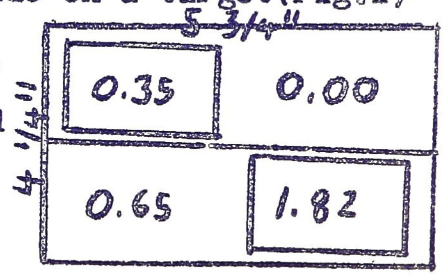

FIG. 1

Illumination was supplied by four 500 watt G.E. RSP-2 Spotlamps. The exposures were made arbitrarily with three replicates at 1500, 5000 and 17,000 footcandles, the corresponding voltages being 40, 60 and 220 volts. Line input voltage was 123 and was constant on the scale. The camera lens was set at f 5.0 and remained constant throughout the exposures. Illumination level and evenness was checked with the Fastax Exposure Meter WF327. The nine rolls were randomly spliced head to tail to produce one large roll for processing. Sensitometric strips were placed at the head and at five other arbitrary positions within the roll. Development was in a modified D-76 formula for 7 minutes.

An error was made in that the timing device in the camera was not activated during exposure. To compensate for this, blank rolls were exposed with the identical equipment and the correct measurements were transferred to the test rolls. This resulted in a total of two hundred and forty densities within each frame speed tested. It is assumed that this size sample is sufficiently representative of the population to enable a statistical analysis.

STATISTICAL PROCEDURE

The investigation was designed to produce a graphical illustration of the change of density(ΔD) with the change in frame speed. The twenty densities on each roll(the sub-group), were added, the sum being divided by twenty to obtain the mean($\bar{X}$). The three means of each frame speed(and for each of the four densities),werecompared using the Student's"t" Test(1).

In thås test, the Null Hypothesis is assumed. This hypothesis states that there is no significant difference between the two means tested. The test is then conducted to determine if the Hypothesis is accepted or rejected. If rejected, there is a <u>statistical significant difference</u> between the means. If the hypothesis is accepted for runs 1 and 2, the test is made between the means of runs 2 and 3. If again accepted, it is assumed that there is no difference between the means of the three runs and the $\bar{X}$'s are averaged to obtain a $\bar{\bar{X}}$. This test was carried out for each of the four densities at the three exposure speeds, a total of twenty-four tests. The twelve $\bar{\bar{X}}$'s obtained are the points plotted on the graph resulting in four curves. The method is illustrated in the sample calculations that follow.(2).

<u>800pps.</u>

RUN 1 Dens.A	RUN 2 Dens.A
.87	.88
.90	.87
.87	.85
.90	.86
.89	.87
.89	.90
.87	.88
.85	.86
.92	.87
.88	.88
.83	.85
.89	.86
.90	.85
.89	.84
.92	.85
.90	.83
.88	.88
.89	.89
.89	.88
.88	.89
$\Sigma X_1 = 17.71$	$\Sigma X_2 = 17.34$
$\Sigma X_1^2 = 15.69$	$\Sigma X_2^2 = 15.02$

$\bar{X}_1 = .88$ $\bar{X}_2 = .87$

EQU. 1

$$\hat{\sigma}^2 = \frac{\left[\Sigma X_2^2 - \frac{(\Sigma X_2)^2}{n_2} + \Sigma X_1^2 - \frac{(\Sigma X_1)^2}{n_1}\right]}{n_2 + n_1 - 2}$$

$$\hat{\sigma}^2 = \frac{\left[15.02 - \frac{(17.34)^2}{20} + 15.69 - \frac{(17.71)^2}{20}\right]}{20+20-2}$$

$$\hat{\sigma}^2 = 0.00056 \qquad \hat{\sigma} = 0.0236$$

WHERE: $\hat{\sigma}$ = AVERAGE VARIANCE
n = NUMBER OF SAMPLES
$n_2 + n_1 - 2$ = DEGREES OF FREEDOM

EQU. 2

$$"t"_\alpha = \left(\frac{|\bar{X}_1 - \bar{X}_2|}{\hat{\sigma}}\right)\left(\sqrt{\frac{n_2 n_1}{n_2 + n_1}}\right)$$

$$"t"_\alpha = \left(\frac{|.88 - .87|}{0.0236}\right)\left(\sqrt{\frac{20 \times 20}{20+20}}\right) = \boxed{1.3389}$$

WHERE: $"t"_\alpha$ = CALCULATED t VALUE
LITERATURE VALUE OF $t_{\alpha, D.F.}$ FOR COMP.

WHERE: α = CONFIDENCE LEVEL
D.F. = DEGREES OF FREEDOM

$$t_{.05,14} = \boxed{2.0930}$$

The literature value of "t"(3) is caompared wi th the calculated "t_s" value. If the calculated "t" is smaller than the lit. value, the hypothesis is accepted. The variance is taken into account by the use of equation 1. The hypothesis was accepted in thirteen cases and rejected in one. The confidence level selected was 0.05. The results were examined to determine if there was evidence of any pattern of regularity made by the accepted and rejected data. None was found. This arbitrary arrangement leads to the assumption that a statistical significance exists between the means of duplicate runs in this system. The acceptance of only half of the data illustrates a non-repeatability of the system.

CONCLUSIONS

1. The repeatability of this system is not statisticaly sufficient to warrant averaging of the replicated data.

2. It is assumed that the repeatability is sufficient to show the trend of density change. The means were therefore averaged and curves plotted.

DISCUSSION

The means were averaged and although there is a significant difference between them, the general trend of density change is still apparent. The variances in such a system seem to prohibit statistical repeatability through this method of analysis. It should be noted that extremely accurate knowledge of the density change resulting from reciprocity failure and other factors is not necessarily to the point in many applications.

On the contrary, this information would be extremely hard to obtain in any photographic system.

It is interesting to note the shape of the curves. The illumination levels used would place the exposures on the right side of the reciprocity failure curve and should show decreasing efficiency. This is not true of the curves obtained.

The variables considered as important factors in the system are camera and equipment(including power source), development, storage conditions of the film, illumination fall-off and inherent variations of the emulsion.

All the film had the same emulsion number. Storage conditions were as similar as possible. Illumination evenness was checked with the meter used in practice and was considered sufficient. The density changes between sensitometric strips showed similarity of development throughout the roll. A check was made to determine any correlation between the density changes on the strips and ~~ad~~ changes in the test rolls lying adjacent to these strips. No correlation was found.

The possibility exists that the working area on each roll was offset due to measurement error and/or differences in location between the ~~[illegible]~~ blank and the test roll. However, these working regions are quite large and a random sampling method was used to select the frames. There was very little density change for a considerable distance in front of and behind the working area.

Some suggestions could be made as to determining the cause of the between sub-group variance. If some of these variables could be eliminated or accounted for, more positive results might be obtained. An analysis of variance(4) could be conducted between ~~soem~~ some of the more possible variation causes. By developing the individual rolls seperately and varying processing times, a two factor analysis could be made as to determine the significance of this variable. This might also be accomplished for storage conditions but would be somewhat more difficult. Variations caused by mechanical and electrical factors are necessarily present in practice and are too numerous to account for here.

REFERENCES

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2. ibid.

3. Bennett, Carl A., and Franklin, Norman L., Statistical Analysis in Chemistry and the Chemical Industry, John Wiley and Sons Inc., New York, 1954, pp. 696.

4. ibid. pp. 319-469.

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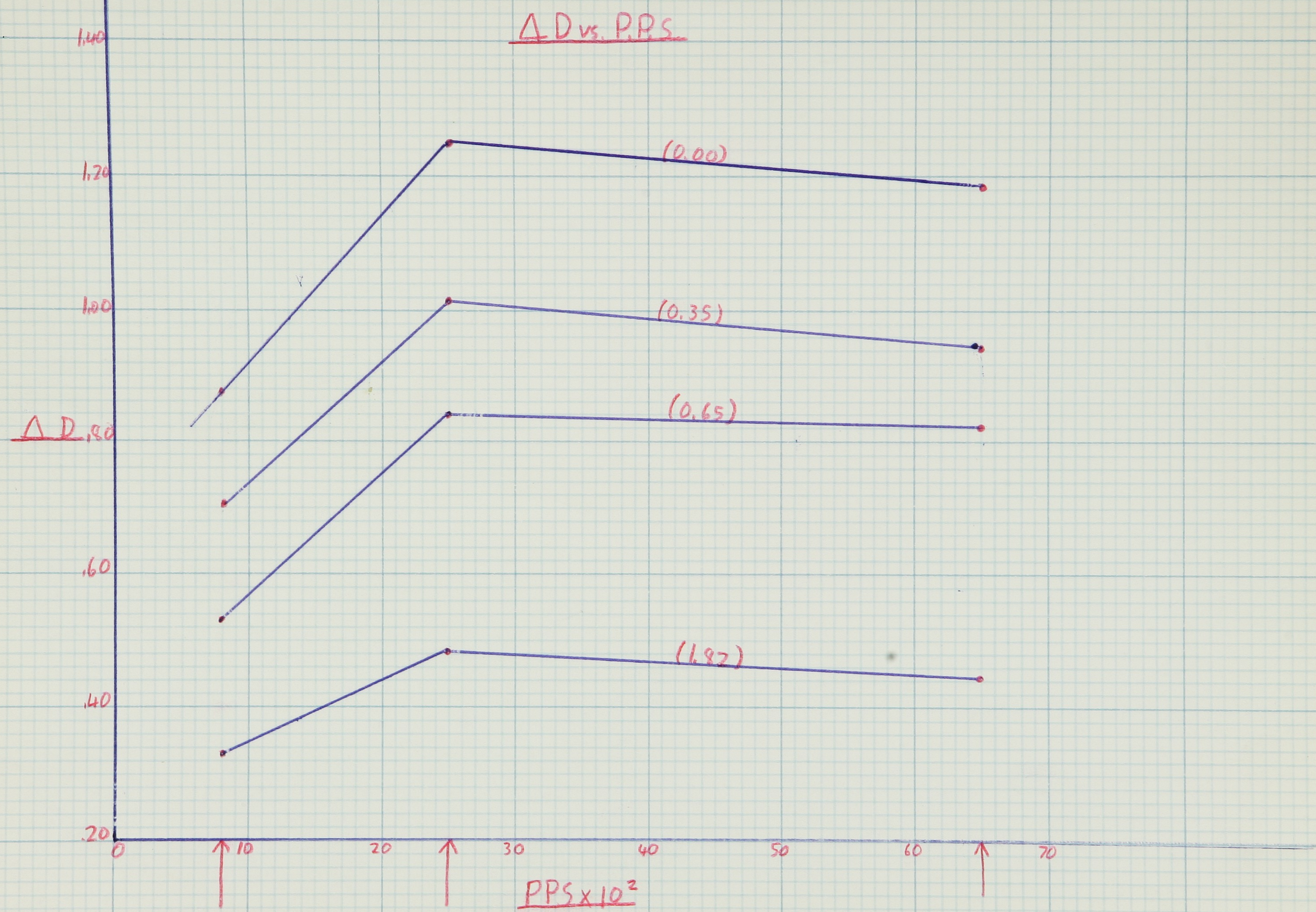

ΔD vs. P.P.S.
(0.00)
(0.35)
(0.65)
(1.82)
1.40
1.20
1.00
ΔD .80
.60
.40
.20
0
10
20
30
40
50
60
70
PPS x 10²